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Geometrical Parameters Evaluation of Optical Coordinate Measurement Using Voronoi Diagram

1. INTRODUCTION

The advancement of technologies of digital image sensors, such as CCD (Charge-Coupled Device) and CMOS (Complementary Metal-Oxide Semiconductor) cameras, gives new abilities to develop of machine vision systems and optical measuring devices. Elaboration of the effective computational algorithms is the basic tasks that must be carried out during design and enhancement of such devices. The methods of images processing and computational geometry are widely used for the handing out of graphical information obtained from the image acquisition system. These methods usually divide the object into geometrical primitives. On the analysis of geometrical primitives are based the common computations of geometrical sizes and their form, orientation and location deviations. One of the basic tasks is the evaluation of distance between two edges or detail's elements, presented as contours. Similar task meets by the thickness evaluation of detail's cross-section. The results of such computations are used for the comparison of actual part's shape and dimensions with the nominal, defined by the specifications.

Even such trivial task as distance evaluation between contour elements coupled with some difficulties. It can't be solved analytically for the most of practical applications. If to consider primitives in form of line segments it can be spoken about analytical distance only in case of segments parallelism. Distances usually evaluated between a point and his projection on the line segment at the opposite side. But also using such kind of evaluation depending on object curvature distances differs by evaluations in opposite directions. It can be spoken about some ambiguity of distances estimated using point-to-segment perpendiculars.

2. **PROCESSING ALGORITHM DESCRIPTION**

The above-mentioned ambiguity can be avoided if instead of perpendiculars (from points of one analyzed primitive to line segments of another primitive) use a circles, inscribed between the considered part section borders (fig. 1). In this case the diameters of the circles uniquely for each analyzed point define the searched distances. The similar task consisting in finding of locus of inscribed circles centers is known in topology and named medial axis transformation (MAT)

[1, 2]. MAT is used for geometrical information compression by skeleton representation, for such task like image recognition and robot motion planning. We consider using the results of MAT in form of inscribed circles radii for the description of distances between part outlines.

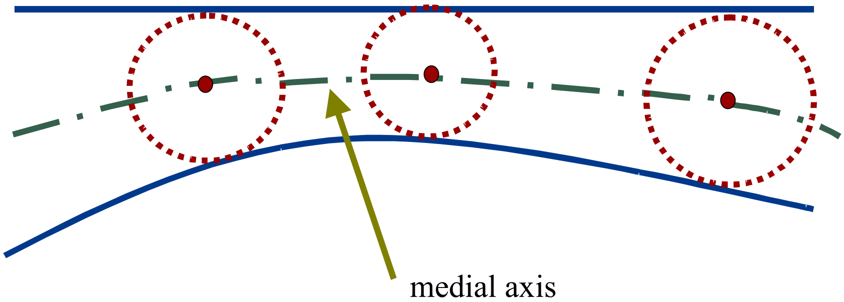

Fig. 1: Inscribed circles and medial axis

For the medial axis evaluation we consider to apply a common approach using Voronoi diagram [3, 4]. It is known, that Voronoi vertices approaches to medial axis when sample density approaches infinity and part is infinitely long. But Voronoi diagram usually consists of vertices lying inside and outside of part contours. The outside vertices obviously must be filtered out. In contrast to the existing methods [5, 6] we propose to use a simplified filtering condition, oriented on the data set in form of part contours obtained from image acquisition system. For effective filtering we consider Delaunay triangulation - dual structure to Voronoi diagram that can be simpler, faster and more effective filtered. Than the filtered triangulation network is converted into Voronoi diagram. The evaluation procedure can be described by the following steps:

- Delaunay triangulation evaluation;
- filtration of triangulation results;
- generation of Voronoi diagram from the filtered set of triangle;
- calculation of the inscribed circles radii.

In the analyzed data set the two primitives (line segments) P_1 and P_2, corresponding to part sides, can be distinguished. The sampling distance is much less as the distance between sides. So, the each triangle used for Voronoi diagram generation must consist of points from both sides. For each "useful" triangle $p_{1i}p_{2i}p_{3i}$ must be satisfied the following condition:

$$\begin{cases} p_{1i} \in P_1 \Rightarrow p_{2i} \in P_2 \cup p_{3i} \in P_2 \\ p_{1i} \in P_2 \Rightarrow p_{2i} \in P_1 \cup p_{3i} \in P_1 \end{cases}.$$

At the next step from the filtered triangles the Voronoi vertices are generated and resulting medial axis is approximated (fig. 2). Than we find the projections of discrete contour points onto the founded medial axis. The projection points are assumed as the centers of the inscribed inside the part contours circles. The radii, evaluated as distances from the contour points to their projections, correspond to the half of local distances between contours. In this way the local distances (thickness) distribution can be evaluated. The accuracy of such evaluation depends on the density of analyzed contour points and grows with it's increasing. Modern image acquisition devices provide high density of acquired image points and allow to raise the evaluation accuracy.

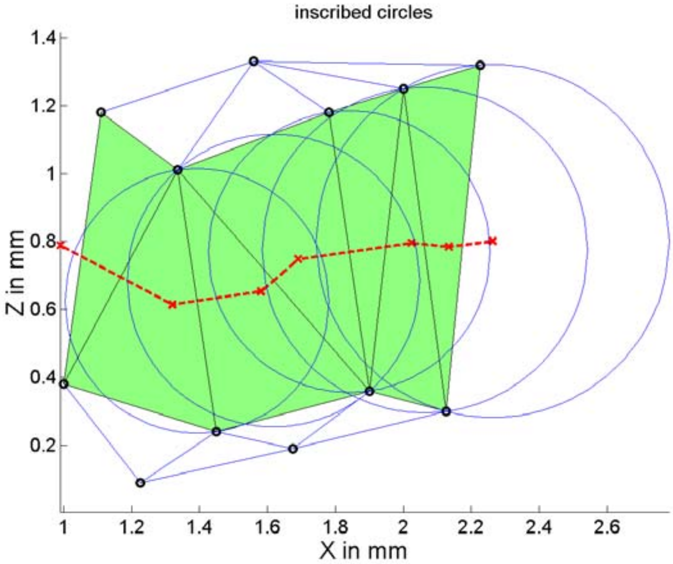

Fig. 2: Filtration (white triangles are filtered out) and generation of medial axis (dashed line)

3. CONCLUSION

The method for the distance distribution along part profile for two-dimensional data sets is proposed. It can be used also for quasi-3D data analysis if to divide the data set in separate cross-sections and to consequently analyze each section. The future works concerning medial axis computation of 3D polyhedron and realization of a fast and robust algorithm for geometrical parameter evaluation from 3D data sets.

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